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# Experimental Investigation of Shell and helical coiled tube heat exchanger using $TiO_2$-Water based Nanofluid

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## ABSTRACT

Shell-and-coil heat exchangers have been used mainly in solar domestic hot water (SDHW) systems because of their high heat transfer and smaller space requirement, their use is also in heat recovery systems for space heating. This project deals with the performance analysis of the shell and helical coiled tube heat exchanger to improve the performance of helically coiled tube heat exchanger using Nanofluid. In this project work, the heat transfer analysis on shell and helical coiled tube was done experimentally using water and $TiO_2$-water Nanofluid at 0.5 % volume concentration. It was found that the performance of heat exchanger was increased while using Nanofluid as compared to that of water. It was found that the use of Nanofluid enhances the convective heat transfer coefficient and overall heat transfer coefficient significantly.

***Keywords: Heat exchanger, Nanofluid, Heat transfer, Nanometer***

## 1. INTRODUCTION

Heat transfer can be enhanced by employing various techniques and methodologies, such as increasing either the heat transfer surface or the heat transfer coefficient between fluid and the surface that allow high heat transfer rates in a small volume. Cooling is one of the most important technical challenge facing many diverse industries, including microelectronics, transportation, solid-state lighting, and manufacturing.

Therefore an urgent need for new innovative coolants with improved performance. The addition of micrometer–sized particles to the base fluids shows an increment in the thermal conductivity of resultants fluids. But the presence of micro-sized particle in a fluid poses a number of problems. The curved shape of the tube causes the flowing fluid to experience centrifugal force. The extent of centrifugal force experienced depends on the local axial velocity of the fluid particle and the radius of curvature of the coil. The fluid particles flowing at the core of the pipe have higher velocities than those flowing near to the pipe wall. Thus the fluid particles flowing close to the tube wall experience a lower centrifugal force than the fluid particles flowing in the tube core. Thermal conductivity is an important parameter in enhancing the heat transfer performance of a base fluid. Since the thermal conductivity of solid metals is higher than that of fluids, the suspended particles are expected to increase the thermal conductivity and heat transfer performance. Many researchers have reported experimental studies on the thermal conductivity of Nanofluids.

The temperature oscillation method, the steady-state parallel plate method, and transient hot-wire method; have been employed to measure the thermal conductivity of Nanofluids. However, the transient hot-wire method has been extensively used by many researchers. Due to higher density of chips, design of electronic components with more compact makes heat dissipation more difficult. Advanced electronic devices face thermal management challenges from the high level of heat generation and the reduction of available surface area for heat removal. $TiO_2$ 35.4 nm, in water resulted in thermal conductivity enhancement in the range of 3% to 10% in two studies but up to 25% in another study.

The thermal conductivity enhancement for the Nanofluids with 25 nm particles was lying in between that of 35.4 and 62.4 nm, which cannot be explained. Murshed et al. observed higher enhancement with85- and 162-nm-sized particles at 1 vol. % compared to the Nanofluids with 2.5 % of 28-nm particles in ethylene glycol-based $TiO_2$ Nanofluids. The authors have demonstrated that 85-nmparticles showed higher thermal conductivity enhancement at 1 vol% compared to similar data reported earlier used 15- and 62.4-nmsizedparticles, observed higher thermal conductivity enhancement for larger Nanoparticles in ethylene glycol-based Nanofluids. The results cited here do not correlate the size. Nanoparticles in Nanofluids form a protective film with low hardness and elastic modulus on the worn surface can be considered as the main reason that some Nanofluids exhibit excellent lubricating properties, friction reduction and Magnetic sealing.

M.R.Salimpour et al (2008) experimentally investigated the heat transfer coefficients of shell and helically coiled tube heat exchangers. Three heat exchangers with different coil pitches were selected as test section or both parallel-flow and counter-flow configurations. [1]. It was found out that the shell-side heat transfer coefficients of the coils with larger Pitches are higher than those for smaller pitches. Finally, based on the results of this study, two correlations were developed top predict the inner and outer heat transfer coefficients of the coiled tube heat exchangers. Nasser Ghorbani et al (2010) experimentally investigated the mixed convection heat transfer in a coil-in-shell heat exchanger for various Reynolds and Rayleigh numbers, various tube-to-coil diameter ratios and dimensionless coil pitch. [2] The modified effectiveness decreased with increasing mass flow rate ratio. The Effectiveness −NTU relation of the mixed convection heat exchangers was same to those of a pure counter-flow heat exchanger. P.C. Mukeshkumar et al (2012) studied the heat transfer characteristics by changing the parallel flow configuration into counter flow configuration under laminar flow regime. The Al2O3 / water Nanofluid at 0.4% and 0.8% particle volume concentration were prepared by using two step methods. [3] It is found that there is no much impact of changing flow direction on overall heat transfer coefficient. Because both in parallel flow and counter flow conditions, the tube side flow passes perpendicular direction to the shell side flow. B.Farajollahi et al (2009) studied the heat transfer characteristics of c-$Al_2O_3$/water and TiO2/water Nanofluids in a shell and tube heat exchanger under turbulent flow condition. [4]. $TiO_2$/water and c-$Al_2O_3$/water Nanofluids possess better heat transfer behavior at the lower and higher volume concentrations, respectively. For both Nanofluids the experimental results are very close to the Predicted values of available correlation at the lower Nanoparticle volume concentrations. K.Y. Leong et al (2011) measured the convective and overall heat transfer coefficient increased with the application of Nanofluids compared to ethylene glycol or water based fluids. It addition, 7.8% of the heat transfer enhancement could be achieved with the addition of 1% copper Nanoparticles in ethylene glycol based fluid at a mass flow rate of 26.3 and 116.0 kg/s for flue gas and coolant, respectively.[5]. Thermal performance of the heat recovery exchanger is increased with flue gas and coolant mass flow rate. About15.97% heat transfer enhancement was observed for ethylene glycol based 1% copper Nanoparticles when flue gas mass flow rate was increased from 26.3 to 42 kg/s. Vijay P Desai et al (2013) experimentally investigated the hydrodynamic and heat transfer analysis of three different geometries of the tube in tube helical coil. This study was conducted over a range of Reynolds numbers from 2500 to 6700 using cold water in annulus side. [6] The mass flow rates in the inner tube and in the annulus were both varied and the counter-current flow configurations were tested. Cherng-Yuan Lin et al (2011) studied the Nanofluids preparation by both the dispersant and surfactant had the greatest dynamic viscosity and lowest degree of thermal conductivity. [7].

Moreover, the lowestand highest dynamic viscosities were found for the Al2O3Nanofluidsprepared without any surfactant and with both the dispersant and surfactant, respectively. IulianGherasim et al (2010) performed a numerical investigation of the use of an Alumina/water Nanofluid inside a radial flow cooling system. Mean Nusselt number was found to increase with particle volume fraction, Reynolds Number and a decrease in disk spacing. [8]. Nanofluid volume fractions considered were, typically, 0% (distilled water), 2%, 4% and6%. The effects of particle volume fraction, Reynolds number and distance separating the disks on heat transfer enhancement and pumping power were considered. M.A. Khairl et al (2013) investigated the heat transfer coefficient and entropy generation rate of helical coil heat exchanger considering the Nanofluid volume fractions and volume flow rates in the range of 1-4% and 3-6 L/min respectively. They analyzed three Nanofluids namely, CuO/water, Al2O3/water and ZnO/water Nanofluids. [9]. They found that the heat transfer coefficient was improved with the increasing of Nanoparticles volume concentration and volume flow rate, while entropy generation rate went down. MofidGorjiBandpy et al (2010) experimentally studied the mixed convection heat transfer in a coil-in-shell heat exchanger for various Reynolds Numbers and various dimensionless coil pitch. [10].

Water was used as the hot and cold fluid. The coil was formed by using 9.52 and 12.5 mm OD straight copper tubing. The results showed that the increase of coil pitch, shell-side heat transfer coefficient was increased. It is also found that the use of $TiO_2$ -water Nanofluid enhances the heat transfer parameters of the heat exchanger due to its increased thermal conductivity compared to that of other Nanofluids. Due to its compactness and the secondary flow caused by its structure itself, the shell and helical coiled tube heat exchanger is more efficient than other heat exchanger types. For this project work, $TiO_2$-water based Nanofluid was taken to analyse the heat transfer coefficients in the shell and helical coiled tube heat exchanger experimentally. The main objective of the project is to find the convective heat transfer coefficient and overall heat transfer coefficient of the shell and helical coiled tube heat exchanger using water and $TiO_2$-water Nanofluid. To compare the performance of water and Nanofluid as coolant in the shell and helical coiled tube heat exchanger.

## 2. EXPERIMENTAL SETUP OF SHELL AND HELICAL COILED TUBE HEAT EXCHANGER

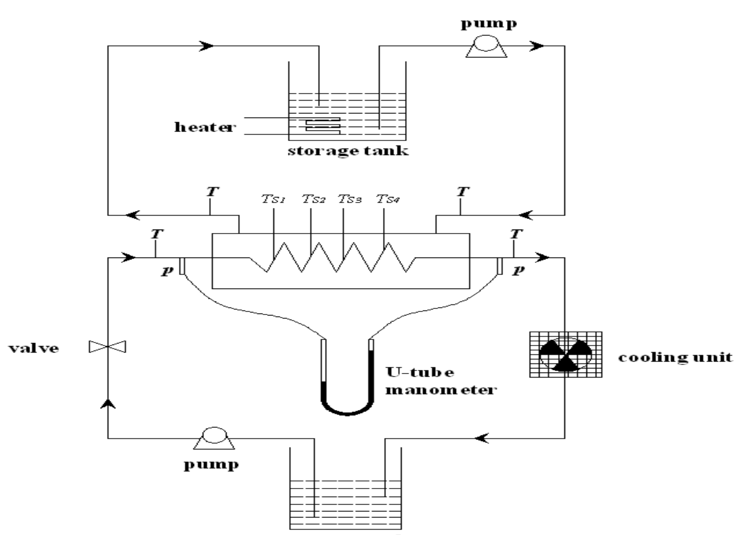


*Fig.1 Experimental Setup of Shell And Helical Coiled Tube Heat Exchanger*

Hot water was taken as hot medium while the cold water and $TiO_2$- water Nanofluid were taken as cold medium. The entrance effect was eliminated by providing the calming section.

The asbestos rope used as insulating medium. Separate pumps were provided to deliver the fluid from reservoir tank to the heat exchanger. Two Rotameters were used to measure the flow rate of hot and cold fluids. Digital temperature indicator was used to indicate the temperatures using K type thermocouples at various positions of shell side and tube side. The accuracy of the thermocouples is 0.1°C. Radiator arrangement was utilized to reduce the outlet temperature of the cold fluid before entering the reservoir. Counter flow arrangement was utilized with hot medium at shell side and cold medium at tube side. Reynolds number for tube side was varied from 1700-7000 while for the shell side it was varied from 660-1250.Initially the hot water at 66°C was allowed to pass through the shell side while the cold water at 33°C was allowed through the tube side. Surface temperatures were taken at various positions of the tube surface. A 1500W immersion heater was attached to the hot water reservoir tank to deliver the hot water at desired temperature. The cold medium was sent through the radiator before entering the reservoir. The same procedure was repeated for the Nanofluid at 0.5 % volume concentration.

## 3. RESULTS AND DISCUSSION

Thus the heat transfer analysis on shell and helical coiled tube was done. The obtained readings were tabulated for water as well as for Nanofluid. It is also found that the use of Nanofluid increases the convective heat transfer coefficient by 6 %as compared to that of water in laminar flow condition and in turbulent flow condition it increases by 26 %. It is found that the use of Nanofluid increases the overall heat transfer coefficient by 6.5 % as compared to that of water.

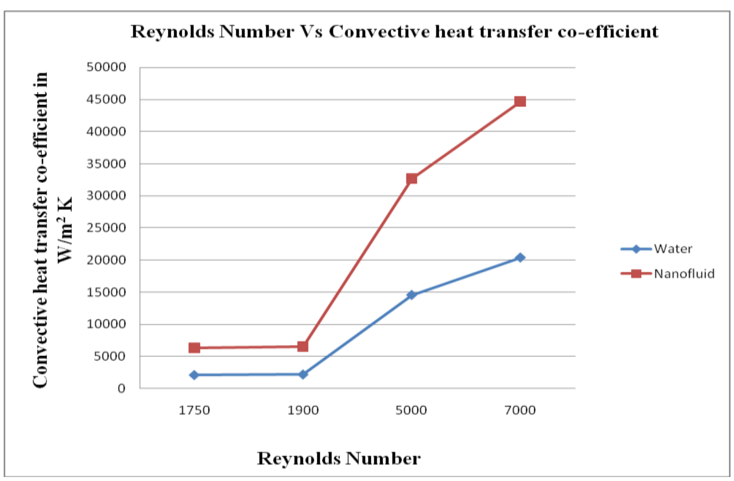


***Fig.2 Reynolds Number Vs Convective heat transfer coefficient for water and Nanofluid***

Fig.2 shows the variation of convective heat transfer coefficient with the Reynolds number for water and Nanofluid. It is found that the increase in Reynolds number increases the convective heat transfer coefficient. It is also found that the use of nanofluid increases 6% of the convective heat transfer coefficient as compared to that of water in laminar flow condition. As well as turbulent flow condition 26% increases.

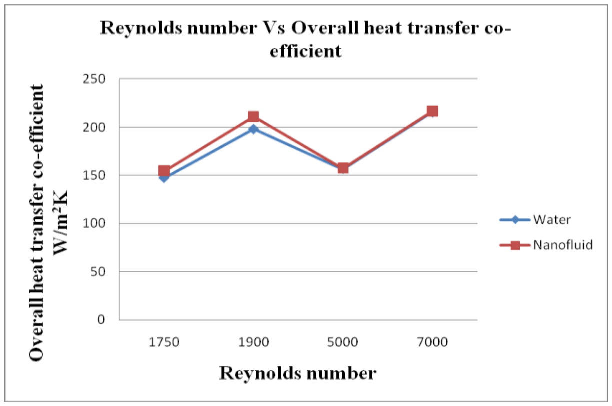


***Fig.3 Reynolds number Vs Overall heat transfer coefficient for water and Nanofluid***

Fig.3 shows that the comparison of Reynolds number and overall heat transfer Coefficient for water and Nanofluid. It is found that the use of Nanofluid increases the overall heat transfer coefficient by 6.5% as compared to that of water. It is also understood that the use of Nanofluid increases overall heat transfer coefficient in laminar than in turbulent region.

## 4. CONCLUSION

In this project work, heat transfer analysis on helical coiled tube heat exchanger was done using water as well as $TiO_2$ Nanofluid. It is understood that the helical coiled tube heat exchanger is more effective compared to other types due to its compactness, high efficiency and the secondary flow caused by its helical structure. From the experimental results obtained, it is found that the use of Nanofluid significantly increases the convective heat transfer coefficient and overall heat transfer coefficient as compared to that of water. Further experiments can be conducted by varying the mass flow rates of hot and cold medium, by changing the volume concentration of the Nanofluid and by using different Nanofluids.

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